S/C #11210-1
Final Report

BioEnergy Development Corp.

888 Kalanianaole Avenue • Hilo, Hawaii 96720

August 3, 1993

Dr. Art Wiselogel
Terrestrial Feedstock Interface Project Leader
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

Dear Art:

Enclosed is the revised final report for the study "Effects of Storage on Eucalyptus for Biomass-to Ethanol and Thermochemical Fuels Project", along with a set of 24 color slides and captions. As requested in your letter of May 25, 1993 I have included mention of the QA/QC measurements for the thermocouples (4th paragraph on pg. 2) and for the wood density determinations (6th paragraph on pg. 3), and am also enclosing copies of the data sheets. On the thermocouple data sheet, the measurements from 9/17/92 are outlined with yellow highlighter.

Copies of this report are being sent to S. Montgomery and M. Yancey with our invoice for the final $2000 payment on this subcontract (copy for you enclosed).

I'm sorry it has taken me so long to get this revision back to you. As you know, we were on half time through the month of June because of lack of funding, and have been busy trying to catch up since then. Also, as we don't have a word processor, I had to retype the entire report to accomodate the revisions.

We will be interested to receive copies of your reports as you complete your analyses of this and the related storage studies.

Encls: original only

cc: Crabb
M. Yancey
S. Montgomery

Aloha,

Thomas H. Schubert
Research Silviculturist

BioEnergy Development Corp.

888 Kalanianaole Avenue • Hilo, Hawaii 96720

July 30, 1993

To: Art Wiselogel, NREL

From: Tom Schubert

Subject: Revised Final Report, Subcontract No. AA-2-11210-1
Effects of Storage on Eucalyptus for Biomass-to-Ethanol and Thermochemical Fuels Project

The Eucalyptus whole tree and woodchip storage piles were constructed on March 18 to 20, 1992. Dr. Art Wiselogel of NREL was present during this period, and supervised selection and placement of the trees in the whole tree pile and insertion of the whole tree thermocouples. He also supervised construction of the woodchip pile, placement of the pile thermocouples and auger access tubes, and preparation of the woodchip subsample bags to be placed in the tubes.

The feedstock for the storage piles was an 11¼-year-old Eucalyptus saligna Sm. plantation in Section 001 of Field 27B at Kamae, island of Hawaii. Elevation is about 300 m, and the soil is Akaka silty clay loam (Thixotropic isomesic typic Hydrandept), with the following description:

> Slope 0-10%; moderately well drained silty clay loams formed in volcanic ash - surface layer of dark reddish-brown silty clay loam about 15 inches thick, subsoil is reddish-brown to dark reddish-brown silty clay loam more than 57 inches thick. Surface layer is strongly acid, subsoil is strongly acid to medium acid. This soil dehydrates irreversibly into fine gravel-size aggregates.

The plantation was established in December 1980, using container-grown seedlings raised from seed collected locally on the island of Hawaii. Initial spacing was 1.5 by 1.5 m. A total of 132 trees was felled using a chain saw on March 16, 1992. Diameters ranged from 3.4 to 34.2 cm, and heights from 8.5 to 32.7 m (see stand table below):

Dbh class	Avg. Ht.	No. of stems
2.1 - 8.0 cm	13 m	32
8.1 - 13.2	18	36
13.3 - 18.4	27	31
18.5 - 23.6	27	16
23.7 - 28.8	32	14
28.9 plus	33	3

The trees were skidded to the roadside on March 18, and chipped using an Eager Beaver chipper on March 19 and 20. The chip storage pile was placed on the north side of a field road intersection, with a Eucalyptus stand

similar to the one that was felled immediately adjacent on the east side (photo 1). The whole tree pile was on the south side of the same intersection, with the long axis of the stems oriented approximately east to west and the butt ends on the west. Because the whole trees were 8 to over 20 m long, they were not placed in vertical piles but were left in a loose pile on the ground, 2 to 3 trees deep and containing about 30 trees (photo 2). Not all of the remaining trees were used to construct the chip pile; the butt ends of some of the larger trees were too big to go through the chipper, and when the pile was about 10 ft. high the chipper broke down, so it was decided to "leave well enough alone" at that point. The entire chip pile consisted of E. saligna feedstock chips; in other words, it did not have E. saligna chips only on the interior and exterior, with a layer of different hardwood chips in between as was suggested as an option in the Statement of Work.

The thermocouples in the chip pile were located and numbered somewhat differently than described in the SOP Manual. Thermocouples to measure the interior temperature were installed on the west (No. 13), east (15), and north (16) sides of the pile. Thermocouples to measure surface temperature at the base of the pile were installed on the east (11) and south (12) sides of the pile; the thermocouple at the apex of the pile was No. 14 as specified in the SOP Manual.

The bark on the whole tree stems was quite thin, therefore each thermocouple was installed by making a slit in the bark and inserting the probe, then securing it with duct tape wrapped around the stem (photo 3). The tape tended to deteriorate and become brittle with time, and as the bark dried out several of the thermocouples became quite loose (photo 4); they were all retaped on June 29. However, by the middle of August the bark over thermocouples 212 and 241 had split so much that their probes were no longer under the bark but held only by the duct tape.

All thermocouples were calibrated as specified in the QA/QC procedures prior to insertion on March 18 by Art Wiselogel and Tom Schubert, and again after pile dismantling on Sept. 17, 1992 (copy of calibration measurements attached).

Thermocouple temperature readings were begun on March 23, and were taken daily Monday through Friday until April 20 (except for Good Friday, 4/17) and once a week (every Monday except for Memorial Day 5/25 and Labor Day 9/07) thereafter. An aluminum paint roller tray, with a screened hole and tube draining into a collection bottle at the lower end, was placed in the chip pile on March 26 to collect runoff water samples (photo 5). The tray gradually became filled with woodchips, which did not prevent water from reaching the collection bottle, and the lower end of the tray gradually took on a rusty appearance during the ensuing 2½ months.

A collection bottle for rainwater was installed on a stake near the chip pile, also on March 26 (photo 5). Water samples were forwarded to NREL about once a week; however, during March, April, and May there was frequently

very little water in the rain bottle even though the runoff bottle was usually at least half full. Comments on water samples:

4/02 - Runoff sample bottle froze while stored in refrigerator.
6/08 - Drowned spider in rainfall collection bottle.
6/15 - Shook runoff collection bottle to loosen sediment in bottom, some of which was included in sample bottle. Both collection bottles were then rinsed with rainwater.

Thermocouple temperatures and water samples were taken by Tom Schubert, except on 4/15, 4/27, 5/04, 5/11, 5/18, and 5/27, when they were taken by Aileen Yeh. Sampling time was between 10:30 to 11:30 AM, except at 12 noon on 3/25, and between 9:30 to 10:30 on 5/18, 6/01, 6/29, 7/13, 7/27, and 8/24. Weather was usually partly cloudy to sunny with a light breeze, except as follows:

Overcast and drizzling - 3/25, 3/31, 4/01, 4/03, 7/20, and 9/14.
Foggy and rainy - 4/27.
Heavy rain - 7/27.

The ambient air temperature fluctuated $2^{o}C$ or more, depending on the amount of wind, and a rough average was recorded after watching these fluctuations for about a minute before beginning the thermocouple temperature readings each time.

The chip pile was shaded by the adjacent Eucalyptus stand until afternoon, thus there was no direct sunlight on it when temperatures were measured. In contrast, several of the thermocouples in the whole tree pile, especially 212, 222, and 232, had direct sunlight on them at times, depending on cloud conditions. The temperature of 232 increased by 4 degrees during a 5 minute period on 4/16 as it went from shade to bright sunlight. Therefore, the temperatures of the whole tree thermocouples were recorded as quickly as possible after the thermometer was plugged in each time, once the reading had initially stabilized.

Rainfall and temperature data were obtained from the "Honohina mauka" weather station of the Mauna Kea Sugar plantation system. This station is located about 2 miles northwest of the storage site at an elevation of 358 m. Accumulated rainfall was recorded from 12:01 AM to the following midnight each day. Relative humidity data will be obtained by Dr. Wiselogel from the NOAA station at Hilo airport (General Lyman field, elevation 8 m) about 15 miles southeast of the storage site.

Increment cores and woodchip samples for % moisture and density determinations were obtained and analyzed as specified by Aileen Yeh. This included weighing the standard wood block as called for in the QA/QC procedure. Wet weights of the block fluctuated from 7.2 to 7.8 g, and dry weights from 2.5 to 3.1 g (copy of calibration measurements attached).

Copies of the % moisture and density determination data sheets have been forwarded to Dr. Wiselogel. Specific comments are as follows:

4/06 - The increment cores were too small to be weighed accurately on the scale. After consultation with Dr. Wiselogel, it was decided to take 3 cores instead of 1 at each location, starting on 5/04.

5/18 - Because 3 cores were taken at each diameter, and due to drying and splitting of the stems, it has become very difficult to take additional cores at the 2-inch diameter on the designated trees. After consultation with Dr. Wiselogel, it was decided to take stem discs instead of cores for the 2-inch diameter (212 and 222) from a different tree stem in the whole tree pile on 5/18 and 6/29, and from the originally designated sample trees on 8/24 and 9/14. On 7/27 increment cores were taken from all diameters.

7/07 - Electrical blackouts caused problems with the balance when weighing.

7/27 - Heavy rain during sampling resulted in all cores, and especially the woodchip samples from the pile surface, getting wet.

8/24 - There was a long split in the stem where the disc for the 212 sample was taken, so the disc was partially wet. Also, the woodchip samples from the pile surface were very wet.

9/14 - The woodchips from the pile surface were wet and gray in appearance, with white fungal hyphae growing through them. The chips in the access tube were also wet but appeared to be in good shape otherwise.

The initial 200-lb. woodchip sample was collected on March 20. The subsequent samples from the whole tree pile (photo 6) and from the woodchip pile access tubes (photo 7) were taken as follows: 3¼ weeks on April 13; 6½ weeks on April 29; and 13 weeks on June 17. The final whole tree pile sample at 26 weeks was taken on Sept. 14, and the final 200-lb. sample from the chip pile on Sept. 16. The whole tree stems for 3¼, 6½, and 26 weeks were all processed with the HSPA chipper; at 13 weeks the Mauna Loa chipper was used. All samples were forwarded to NREL by Federal Express as specified.

Dr. Wiselogel was present once again when the study was terminated and the woodchip storage pile was dismantled on Sept. 16, 1992. He took photographs and observations, and participated in the collection of the final 200-lb. sample. Contrary to expectations, there was moisture throughout the chip pile at the end of the 26-week period. The driest chips were beneath the pile runoff collection tray.

There was no marked temperature increase inside the woodchip storage pile during the 26-week period. In the whole tree pile, temperatures under the bark seemed to fluctuate with ambient air temperatures and sunlight. Shown in the table on the next page are starting, 13 week, and ending temperatures for each thermocouple, as well as the highest and lowest temperatures recorded by each thermocouple during the study.

Thermocouple No.	Temperature (degrees Centigrade) 3/23/92	6/15	9/14	Highest(date)	Lowest(date)
11	22.5	23.7	28.3	28.3(8/10 & 9/14)	19.7(3/26,3/30 & 4/16)
12	23.7	24.8	26.3	26.4(8/10)	20.8(4/13 & 5/11)
13	30.1	33.0	30.0	39.2(8/03)	24.0(5/11)
14	31.1	31.4	24.5	35.8(3/26 & 3/27)	22.2(5/11)
15	30.5	29.8	28.2	33.0(7/06)	23.6(4/20)
16	29.7	31.8	30.9	36.0(8/10)	25.4(5/11)
211	27.7	40.4	24.4	46.4(5/27)	20.2(4/27)
212	30.7	44.8	24.1	48.7(4/08 & 5/27)	20.8(4/27)
221	26.7	41.4	24.5	44.6(5/27)	21.0(4/27)
222	31.8	46.9	24.8	52.0(5/27)	21.0(4/27)
231	30.4	42.1	24.3	50.8(5/27)	20.8(4/27)
232	32.6	37.3	24.7	53.3(4/08)	21.4(4/27)
241	28.3	47.5	24.8	47.5(6/15)	20.8(4/27)
242	28.5	36.5	23.8	37.3(4/20)	20.8(4/27)
Ambient Air	21.9	26.2	23.0	31.1(5/27)	18.6(4/03)

For the woodchip samples periodically extracted from the storage pile, percent moisture gradually increased from about 57% to 65% during the 26-week period, and the density gradually decreased from 0.415 to 0.336 (average of 3 samples from interior and from 1 and 6 ft. on exterior of pile). In contrast, for the increment cores from the whole tree pile, percent moisture gradually decreased from about 59% to 42%, and density gradually increased from 0.286 to 0.412 (average of 6 samples, 2 each at 2, 3, and 4 inch diameters).

All data files were entered into the specified computer format by Aileen Yeh, and checked by Tom Schubert. The diskette is being forwarded to Dr. Wiselogel.

Photo captions:

1. Chip pile, with adjacent Eucalyptus stand on east side.
2. Whole tree pile on south side of field road.
3. Thermocouple installed beneath bark and duct tape. Thermometer plug is inside plastic "ziplock" bag.
4. Whole tree thermocouple showing splitting of bark and deterioration of duct tape.
5. Rain collection bottle on stake, with runoff collection tray and bottle in center of photo, and one of access tubes just to left of stake.
6. Whole tree and access tube 13 week samples.
7. Access tube 13 week sample being withdrawn. Thermocouple lead and plug (in bag) visible below tube.

Encls: 7 photos)
5 lab data sheets) with original only
computer diskette)

cc: T. Crabb
M. Yancey
S. Montgomery